that are associated with the use of diffusion or turbulent flame burners in compact reformer apparatus.

However, there are practical limitations regarding the use of an annular reaction chamber for small-scale reformers having hydrogen production rates of less than about 1500 SCFH. It is well known that the heat transfer coefficient of gaseous reactants contained within an annular reaction chamber is directly related to the velocity of the gaseous reactants within the annular space. In order to limit the reaction chamber wall temperature, the velocity of gaseous reactants within the annular space must be sufficiently high to absorb the radiant heat flux that impinges on the reaction chamber tube walls. However, for very small-scale reformers, this requires that the width of the annular reaction chamber space be small. It is common practice in the art to limit the maximum diameter of the catalyst particles packed within an annular space to less than 20 percent of the width of the annular space in order to ensure that the catalyst is evenly distributed within the reaction chamber and to prevent gas channeling along the walls of the reaction chamber. However, for an annulus having a

small width dimension, this requires use of catalyst particles of particularly small diameters thereby resulting in an undesirably high pressure drop through the catalyst bed.

The benefits of a flameless radiant burner for use in compact catalytic reaction apparatus of annular reaction chamber geometry are known. For small-scale reformer applications, a tubular reaction chamber geometry is preferred over annular reaction chamber geometry in order to simultaneously achieve high heat transfer coefficients and low pressure drops within the reaction chamber.

There is need for a compact endothermic catalytic reaction apparatus as embodied in the present invention to achieve the objects of compact design, while avoiding the problems of flame impingement, excessive reaction chamber wall temperatures, and excessive reaction chamber pressure drop by application of a tubular reaction chamber that is heated by the radiant burner. The tubular endothermic reaction chamber as disclosed herein employs a combination of catalyst particle sizes and reactant mass velocities to control the reactor

pressure drop and the maximum reaction chamber tube wall temperature within certain needed limits; and the radiant burner is operated at specific ranges of combustion intensity and excess air to control surface temperature of the radiant burner within certain needed limits. The present invention extends the practical range of tubular endothermic reaction chamber geometry that can be used in combination with radiant burners for converting hydrocarbon feedstock to useful industrial gases.

SUMMARY OF THE INVENTION

It is the general object of this invention to provide a novel endothermic catalytic reaction apparatus for the production of industrial gases from a hydrocarbon or methanol feedstock that is simultaneously compact, thermally efficient, has improved life expectancy and low pressure drop, and is particularly well suited for the small scale generation of useful gases for fuel cell applications in the range of 1 k W to 50 k W.